DOCUMENT RESUME

ED 303 431 SP 030 848

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TITLE Factors Influencing Movement Consistency during the Learning/Performance of Perceptual Motor Tasks.
PUB DATE 4 Mar 88
NOTE 15p.; Paper presented at the Annual Conference of the Southern District of the American Alliance for Health, Physical Education, Recreation and Dance (Little Rock, AR, March 4, 1988).
PUB TYPE Speeches/Conference Papers (150) -- Information Analyses (070) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Athletics; Kinesthetic Perception; Perceptual Motor Coordination; *Perceptual Motor Learning; *Physical Activities; *Psychomotor Skills; *Sensory Integration

ABSTRACT

Literature examining elements influencing the production of consistent human movement is reviewed in this paper. The review is limited to theoretical papers and research studies on sport-related tasks that utilize actual representations of movement, e.g., film, electromyogram, or videotape; rather than movement only implied from goal attainment, e.g., error scores in target accuracy. The existent research and theory concerned with human movement consistency during perceptual motor task performance/learning repeatedly identifies three major influencing factors: (1) type of task/environmental demands; (2) amount of practice with the task; and (3) skills level of the individual. A selected reference list is included. (JD)

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FACTORS INFLUENCING MOVEMENT CONSISTENCY DURING THE LEARNING/PERFORMANCE OF PERCEPTUAL MOTOR TASKS

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Refereed Paper Presented at the Annual Conference of the
Southern District of the American Alliance of Health,
Physical Education, Recreation, and Dance
in a Lecture Format

Little Rock, Arkansas

March 4, 1988

CE050 842

FACTORS INFLUENCING MOVEMENT CONSISTENCY DURING THE LEARNING/PERFORMANCE OF PERCEPTUAL MOTOR TASKS

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The purpose of this paper is to review the literature examining elements influencing the production of consistent human movement. The primary contribution of this study is that it was completed at a time when the emphasis of the basis for motor control research has changed toward utilizing actual movement rather than movement implied from the consistency of the goal attained. Components of the studies/papers included in this review are presented in relation to several constructs, such as: (a) timeliness, (b) ecological validity, (c) practicality, and (d) usability in applied settings (i.e., teaching, coaching). The review was limited to theoretical papers and research studies on sport related tasks that utilize actual representations of motor movements. A selected reference list is included in the handout.

Theoretical Papers

The theoretical papers reviewed were produced by authors with differing backgrounds, i.e., Arend, Fitts, Gentile, Glencross, Higgins, and Whiting; and were written for different purposes. Though movement consistency during perceptual motor task performance/learning was the focus within each work, the influencing characteristics examined (e.g., environmental demands) and specific objectives (e.g., teacher application) varied across studies.

Whiting, in Acquiring Ball Skill (1969), identified several key points based on his previous research. He suggested that higher levels

calculated. Hoffman's (1974) results suggested that: (a) although there were changes in jumping technique, learning as measured by performance over time did not occur; and (b) although expected decreases in variability did not take place, the type of task was probably a factor. In explaining the results, Hoffman (1974) suggested: (a) subjects were trying to increase distance each trial, not simply to imitate movements, and (b) distance-oriented closed tasks may be affected differently by practice than closed skills concerned with accuracy.

Tyldesley and Whiting (1975) defined timing as "an observable product of man's attempts to adjust his behavior to the requirements of the external environment (p. 172)." The concept of timing is usually thought of only in terms of anticipation while the movement production time is often overlooked. The decrease in temporal uncertainty which results from the execution of a motor plan is known as "operational timing."

Tyldesley and Whiting (1975) attempted to objectively measure the hypothesis of operational timing using subjects from three skill levels in table tennis as they hit forehand drives on balls which were mechanically served to them at a consistent trajectory. Tyldesley and Whiting (1975) concluded that: (a) novice players showed very little movement consistency and this correlated with their reduced performance outcomes; (b) as the skill level increased, the percentage of the movement under programmed control increased; and (c) the expert performer had greater attentional capacity to devote to other environmental demands, if needed (Tyldesley & Whiting, 1975).

Franks and Wilberg (1984) conducted a study concerning the effects

Spaeth and Higgins (1972) also tested and found support for elements of Gentile's (1972) theory, i.e.: (a) practice of closed skills results in movement techniques becoming more uniform, and (b) during acquisition of an open task, a variety of movement patterns develop to match corresponding environmental conditions. Spaeth and Higgins (1972) had subjects perform dart throwing tasks in a closed and open environment. The results revealed that in early practice of a closed task, movement was diversified, but became more consistent as trials progressed. Initial technique in the temporal/spatial environment was highly varied. As practice progressed, however, movement patterns became more defined, yet adaptable, to match specific environmental demands (Spaeth & Higgins, 1972).

Vorro (1973) studied the effects of training on movement changes in the upper arm during a novel ball throwing task. Means and standard deviations were calculated for the three measures: (a) limb velocity, (b) limb acceleration, and (c) changes in wrist flexion. Vorro's (1973) findings indicated that over practice, subjects began throwing in a more consistent manner by slowing the entire motion while also decreasing the amount of variation in wrist flexion. Vorro (1973) concluded that the reduction in the acceleration and velocity rates resulted in smoother, more consistent mechanical movements and increased throwing accuracy.

Hoffman (1974) examined the effects of practice on performance consistency in a closed skill, a backward jump for distance. Biomechanical measurements were obtained from pictures taken immediately prior to take-off, during take-off and also upon landing. Performance consistency was analyzed and within-subject variability

Slater-Hammel (1948) studied the muscle contraction-movement relationships of a golf swing performed by subjects of above average golf ability. The contraction-movement relationships were shown to differ greatly between subjects; however, within subjects, contraction-movement consistency was shown in timing and coordination across all trials. Thus, a well developed habit pattern was demonstrated for all intermediate-level golfers, but their habit patterns tended to differ from each other.

Slater-Hammel (1949) extended his previous research concerning muscle contraction-movement relationships by analyzing the forehand tennis stroke of males possessing "good" tennis ability. The spatial task required subjects to hit a stationary tennis ball which was suspended by an elastic string four feet from the floor. Subjects differed greatly in the timing, duration, and total number of muscular contractions during a stroke; however, the within-subject variation was less than five percent from stroke to stroke. Slater-Hammel (1949) concluded that above average tennis players have well-developed swing patterns.

Del Rey (1971) tested Gentile's (1972) theory that the environmental condition is related to the most effective type of feedback during practice of a fencing lunge with and without variability. Subjects were randomly assigned to one of four treatment groups combining: (a) the presence or absence of videotape feedback, and (b) performing an open or closed task. Del Rey (1971) suggested that the results indicate that KP feedback in the form of videotaping, is useful in improving movement consistency, accuracy, and response latency in closed tasks.

their physical make-up, or morphology, knowledge of the state of the external environment, and a repertoire of cognitive plans in order to formulate, organize, and execute efficient movements. The teacher's role in facilitating efficient movement is, according to Arend (1980): (a) to help learners perform on their own, and (b) to develop error correction abilities.

Glencross (1980) suggested some practical "strategies" for overcoming motor control limitations to facilitate skill acquisition and performance improvement when there is:

1. Certainty that a cue will occur, initiate the response prior to the actual signal to reduce temporal uncertainty and avoid a time lag.

2. A need to focus on and act upon fewer, more salient cues.

3. A need to group stimuli more holistically and recognize/act upon the total environmental situation.

In summary, performers must conceptualize what is necesary to refine skillful accomplishment of a task, i.e.: (a) if the environmental demands and goal are constant, then repetition of movement is required; and (b) if the environmental demands and goal are varied, then movement diversification is needed (Gentile, 1972; Higgins, 1972; Arend, 1982).

Research Papers

The details of the studies are identified on the handout (attached). You are encouraged to refer to that delineation as I share only the purpose and conclusions of each study.

feedback with the possibility of utilizing videotape replay to enhance this even further by allowing the performer to see their movment; and (b) practice should be provided with systematic variation of regulatory stimuli to help the learner develop a repertoire of movements to match potential game situations (Gentile, 1972).

Higgins (1972) stated that the two mechanisms responsible for producing adaptive movements in humans are: (a) the voluntary control system and (b) the postural control system. Because performed movements must constantly match the environment for success to occur, the performer uses these control systems in order to adjust to various environmental situations. When precise movements are required to match either predictable or unpredictable environmental demands, the voluntary control system is responsible. It utilizes preprogrammed movements and is considered to be an open-loop function. The postural control system, a closed-loop function, guides the movement of the body in and through space.

During skill acquisition, consistency of movement and consistency of goal-attainment are both important. Information pertaining to variations in the displacement, acceleration, and velocity of body and/or limb segments during movement is critical to the performer (Higgins, 1972).

Skillful performance of a complex human movement is seldom found to be a purely innate ability, rather, portions of the movement are acquired through practice, then combined into a whole action. Arend (1980, 1982) discussed this process through which skillful movements are developed in terms of factors which regulate movement organization for efficiency. She indicated that performers need an understanding of

of movement consistency were displayed during skilled execution of closed tasks than during skilled execution of open tasks. The variation in the latter was suggested to be due to: (a) changes in the performer's spatial orientation, and (b) the timing of individual muscular contractions. Whiting (1969) also indicated that highly skilled performers tend to exhibit greater consistency than beginning level performers in both timing and movement patterns from trial to trial.

According to Gentile (1972) and Fitts (Fitts & Posner, 1967) acquisition of goal-directed, adaptive movements can be divided into two distinguishable stages, cognitive and associative. During the beginning or cognitive phase, the performer explores potential movement patterns and attempts to conceptualize what is needed. In the intermediate or associative phase, however, the learner focuses on refinement of the previously learned skill to reach a criterion level of performance (Gentile, 1972; Fitts & Posner, 1967). Regarding the development of consistency of movement, Gentile suggested the following points. The cognitive phase of skill acquisition is marked by: (a) the learner's recognition of the goal, (b) the learner's determination of the nature of the correct motor pattern to accomplish the goal, and (c) the environmental conditions, whether closed or open, control which movements will facilitate goal attainment (Gentile, 1972). The intermediate or associative phase of skill acquisition consists of: (a) increased movement consistency (fixation) for closed tasks, and (b) improved appropriate movement diversification in open tasks (Gentile, 1972). Gentile (1972) also suggested that to facilitate closed skill acquisition: (a) augmented KP is the best type of

of practice on movement consistency during the acquisition of a pursuit tracking task. They determined that early in learning, responses were varied as subjects often adjusted their movements and altered their cognitive plans. In later practice, the responses began to vary in a more similar manner. During early trials when responses were inconsistent, the decrease in variability was equally distributed throughout all phases of a movement sequence. As learning progressed, the majority of decrease in response variability over trials was found to be primarily a result of a decrease in variability during the mid-point of each movement. The authors confirmed that performers produce more consistent movements as an outcome of practice. During a single movement sequence, the mid-phase became steadier, while the beginning and ending phases evidenced the greatest intra-individual variability. If subjects had received additional practice trials, potentially the acceleration and deceleration stages would have shown more movement adaptability. On the basis of this study, Franks & Wilberg (1984) suggested that greater attentional focus may need to occur at two times during performance: (a) at the beginning of the movement and, (b) at the completion of the movements.

Conclusions

The existent research and theory concerned with human movement consistency during perceptual motor task performance/learning repeatedly identify three major influencing factors: (a) type of task/environmental demands; (b) amount of practice with the task; and (c) skill level of the individual. The external environment dictates, foremost, whether the performer must concentrate on movement repetition or movement variability to attain the desired goal (Whiting, 1969;

Gentile, 1972; Arend, 1980 & 1982; Del Rey, 1970). Movements must correspond to all environmental conditions for successful task completion (Higgins, 1972). Temporal/spatial tasks are situation-specific and may demand differing movement patterns from trial to trial, while spatial tasks require movements to be "grooved in" or reproduced the same way each time (Higgins & Spaeth, 1972). The degree of previous experience with the task is also shown to directly affect one's ability to reproduce appropriate movements (Vorro, 1973; Hoffman, 1974; Higgins, 1977; Glencross, 1984). Limited practice results in erratic, and often incorrect, movement patterns under both regulatory conditions. As practice continues, however, movements which have been refined become "fixated" or "diversified" in closed and open tasks, respectively, while goal-attainment generally increases (Gentile, 1972). Changes in the variability of the specific movement phases also occur as a result of continued practice (Tyldesley & Whiting, 1975; Franks & Wilberg, 1984). Initially, the acceleration, mid-phase, and deceleration portions display constant and equal variability. Over practice, however, the mid-phase becomes consistent across trials while the acceleration and deceleration phases remain inconsistent. An additional factor related to practice experience which affects movement consistency is the performer's skill level. It has been established that intermediate and advanced-level players exhibit higher degrees of pattern consistency when compared to beginners during the execution of closed or highly predictable open tasks (Slater-Hammel, 1948 & 1949; Whiting, 1969; Tyldesley & Whiting, 1975). Experienced performers appear to preprogram larger portions of the desired movements, consequently producing highly consistent movements from trial to trial

(Tyldesley & Whiting, 1975; Glencross, 1980).

The implications of the present review are directly applicable to most perceptual motor skill teaching/coaching situations. The instructor is responsible for identifying the aforementioned factors while structuring/manipulating practice situations to allow performers to refine their movements and advance from the cognitive through the associative phase (Gentile, 1972). Individuals must comprehend the movement demands required for task completion in specific, often changing, environmental situations. The teacher/coach can help the learner focus attention on other salient demands specific to the sport/activity, as skill level improves and the correct movements become more automatically repeated or varied, thus resulting in higher levels of performance and more consistent goal attainment.

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HANDOUT

AUTHORS	SLATER-HAMMEL (1948)	SLATER-HAMMEL (1948)	DEL REY (1971)	SPAETH & HIGGINS (1972)	VORRO (1973)	HOFFMAN (1974)	TYLOESLEY WHITING (1975)	FRANKS & WILBERG (1984)
Sample Size	4	4	40	2	8	10	Not Given	3
Sex	M	M	F	M	M	M	NG	M
Age	Adult	Adult	College	Children	College	Children	NG	Adults
Skill Level	INT/ADV	INT/ADV	BEG	BEG	BEG	BEG.	BEG, INT, ADV	BEG.
Task	Golf Swing	Modified Tennis Stroke	Fencing Lunge	Dart Throwing	Novel Underhand Ball Toss	Backward Jump for Distance	Ping-Pong Forehand	Cursor Tracking on Oscilloscope
Total Number Trials	600	300	54	200	100	80	170	200
Spatial Temporal/ Spatial	S	S	S	S & T/S	S	S	T/S (Predictable)	T/S
Trial to Trial Variability	N	N	Y	Y	N	N	Y	N
Data Collection Form	EMG	EMG	Form rating; Timing Device	Cinematographical Analysis (Motion Analyzed)	Stroboscopic Photography	High-Speed Photography	Cinema Photography	
Goal Attainment			Proximity to target Response Time	Criterion Number trials Hitting Target	Proximity to target center		Proximity to target	Time on target
Movement	Contraction-Movement Relationship	Contraction-Movement Relationship	Form Rating		Limb velocity and acceleration; changes ulnar flexion	Changes in joint angle, angle of inclination and joint action velocity	Velocity & displacement of joint angles (Wrist & Elbow)	
Results	Consistency shown in muscle timing and contraction of intermediate players	With-in subject variation less than 5%	Videotape viewing is useful in increasing movement consistency & accuracy and reducing response latency in closed tasks for beginners	Early closed task performance was erratic, but became more consistent; during early open task performance, movement inconsistent. Over practice, becomes diversified to match specific environmental demands	Throwing motion becomes more consistent and accuracy increased due to reduction of acceleration, and velocity rates of entire motion	No significant decrease in movement variability. Distance-oriented task may be cause.	Int. and Adv. players demonstrated higher patterns of consistency and goal attainment than beginners	During early learning trials, decrease in variability was equally distributed throughout movement. Later trials, acceleration and deceleration phases displayed normal variance, while mid-phase more consistent.

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